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FLIGHT OF THE INTERPLANETARY AUTOMATIC
STATIONS "VENUS-2" AND "VENUS-3"

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FLIGHT OF THE AUTOMATIC INTERPLANETARY STATIONS
"VENUS-2" AND VENUS-3" •

[HIGHLIGHTS]

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Attention of scientists and of all mankind has for a long time been drawn to planets closest to Earth. Observation of planets from the Earth provided data on their nature; however, because of their remoteness and of the presence of terrestrial atmosphere, hindering the observations, numerous characteristics could not be investigated from ground.

Particularly mysterious is the planet VENUS, which, after the Moon, is our nearest heavenly body. The best terrestrial telescopes allow to distinguish on it details of dimensions of not less than 500-1000 km; however, observations during numerous years failed to disclose any visible details, for the planet's surface is constantly concealed by a continuous opaque cloud layer. Even the rotation velocity of the planet about its axis could not be ascertained precisely until very recently and only radar observations conducted in the USSR and USA in 1960-1962 allowed to estimate the period of Venus' rotation. It was found to be small by comparison with that of the Earth: one convolution about its axis corresponds to 200-300 terrestrial days.

Temperature measurements of planet's surface, conducted from Earth by studying its infrared and "radionoise" emission, gave results which can not, to-date, be definitely explained theoretically: the infrared radiation corresponds to quite low a temperature, near -40°C [and F], while the radionoise emission in micro and centimeter wave bands corresponds to surface heating to some $300-400^{\circ}\text{C}$. These results are presently explained only with the help of various hypotheses in the assumption that the planet's

* О ПОЛЕТЕ АВТОМАТИЧЕСКИХ МЕЖПЛАНЕТНЫХ СТАНЦИЙ "ВЕНЕРА-2" И "ВЕНЕРА-3".

surface is indeed heated to $300 - 400^{\circ}\text{C}$ at the expense of the so-called "greenhouse effect". This powerful effect is induced by the clouds of the planet, capable of letting the solar heat get through to Venus' surface, retaining, however, the reradiation. For heating to such temperatures an extremely high opacity is required of clouds for the infrared rays. This phenomenon still cannot be fully explained theoretically.

In connection with the fact that the hypothesis of "greenhouse" effect is not fully demonstrated, there exist other assumptions, for example, of "nonthermal" origin of radionoise, that is of their generation on account of intensive motion of electrons in the atmosphere or ionosphere.

The investigation of the true physical conditions on Venus, sharply differing from those on Earth, is of exceptional scientific interest. These exciting questions may be resolved only with the aid of space probes, directed into the immediate vicinity of the planet, flying past it at small distances or descending directly into the depth of its atmosphere.

When realizing such probes it is prerequisite to resolve a series of problems of principle, quite new, such as putting these probes (or stations) into interplanetary orbits, the materialization of radio communications over distances of hundreds of million kilometers, the creation of new instrumentation for the purpose of guiding the probes and carrying out measurements, and also the working out of perfect devices for scientific investigations.

By launching the interplanetary automatic stations Venus-2 and Venus-3 the Soviet Union undertook the first serious attempt to carry out a direct investigation of that planet.

APPARATUS OF VENUS-2 AND -3

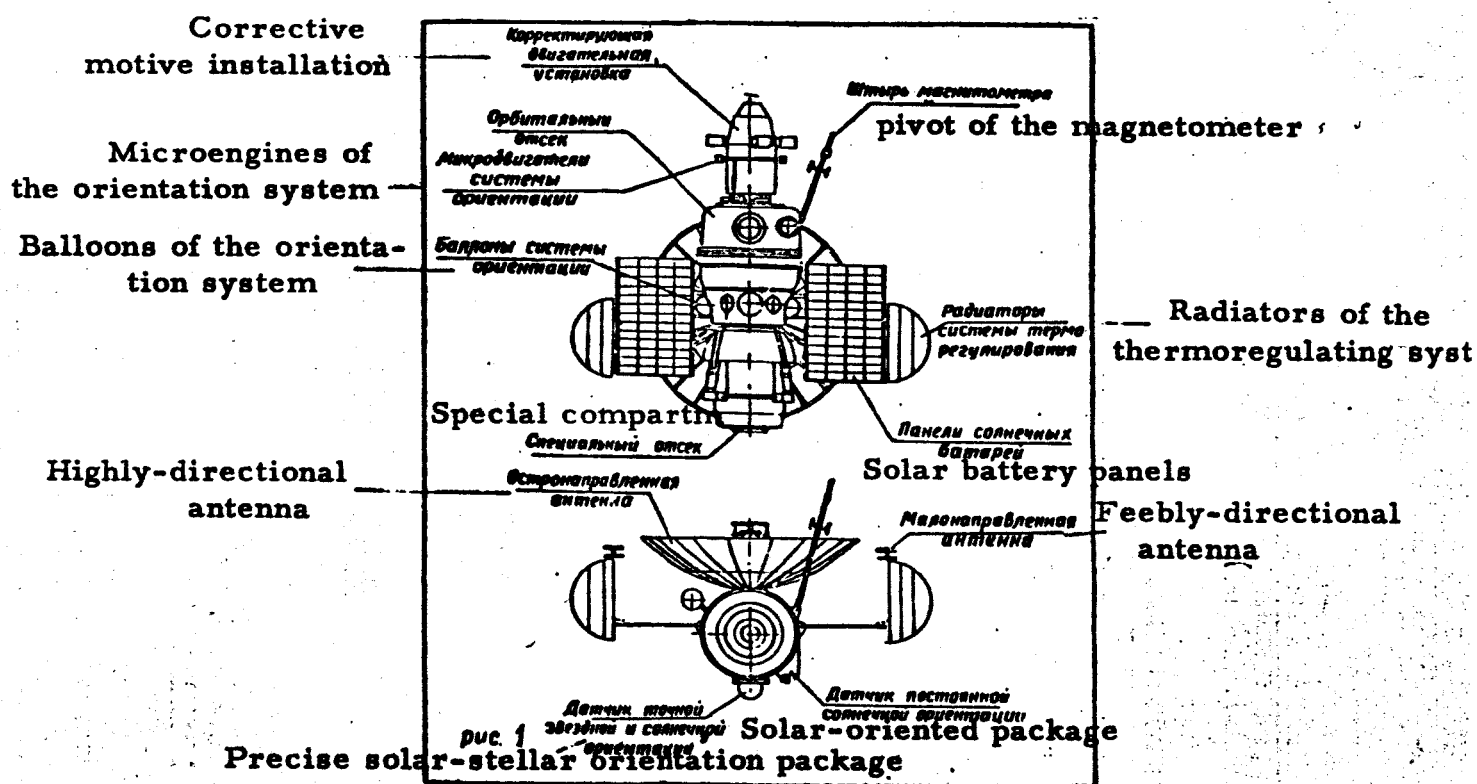
The scientific problems of flight anticipated: at the first stage — the investigations of interplanetary space over the flight trajectory between Earth's and Venus' orbits, at the second stage — the investigation of the nature of Venus' surface.

In order to assure a broad study of the planet, two methods were planned: Venus-2 was supposed to pass at close distance from the planet's surface, effect measurements and take photographs. Venus-3 was expected to

enter into the dense layers of planet's atmosphere and transmit the results of direct measurements of temperature and pressure on the surface.

The general construction of these probes has a great deal in common with that of Mars-1, Zond-1, Zond-2 and Zond-3.

Both, Venus-2 and -3 consist of two hermetic compartments — the orbital and the special (Fig. 1). On Venus-2 a special compartment included the photo-TV device, a centimeter band transmitter, one of the accumulator batteries and part of the electronic apparatus assuring the functioning of the compartment and certain scientific measurements.



A special compartment of Venus-3 is a descendable device, designed in the shape of a sphere of 900 millimeters in diameter, covered by a heat-proof material assuring protection against high braking temperatures.

This device includes decimeter-wave transmitters designed for transmitting to ground the basic parameters of planet's atmosphere and surface, measured by the scientific devices. The landing on surface is realized with the aid of a parachute system.

In the descending apparatus there is a pennant, as shown in Fig. 5.

Prior to blast-off, the descending apparatus was subject to careful sterilization, required to dispose of all microorganisms of terrestrial origin and thus prevent the possibility of contamination.

Thermoregulating radiators are installed on the orbital compartment's surface, alongside with solar battery panels, the propulsion system for trajectory correction and gas jet microengines of the orientation system.

The fundamental apparatus, assuring the operation of the station over the trajectory, is concentrated in the orbital compartment, in which there are disposed the accumulator batteries, the decimeter-band transmitters and receivers, the telemetric commutators, the orientation and correction devices of station's motion and the electronic-optical sensors of station's position in space with the gyroscopic devices.

The electron timer is also situated in the orbital compartment; it is assuring the guidance of all the station's systems, switching on automatically the devices for conducting radiocommunications through preassigned time intervals. Besides, these sessions may be conducted on command from Earth.

A specific thermal regime is required for the normal operation of the station; it is assured by the thermoregulating system. Solar batteries, disposed on two panels, constitute the main source of electric energy for all the station's devices. Buffer accumulators are switched on parallelwise to them.

The transmitters of automatic space probes operating in decimeter and centimeter bands, may be alternately switched onto a highly-directional antenna of paraboloid shape. With the aid of the latter all the transmitter-emitted power is directed at the Earth in a narrow beam, which increases significantly the reliability of radiocommunication, the rapidity and the quality of the transmission. The reception of radiocommand on board is made by way of a feebly-directional antenna, to which it is also possible to switch the decimeter-band radiotransmitter. Thus, though with lesser velocity than at trans-

mission with the aid of the parabolic antenna, radiocommunications may be achieved without orientation at the Earth, somewhat less rapidly, however.

The radioreceivers of the probes receive, besides commands, radio-signals from Earth for the measurement of the distance between the earth and the escape velocity of the probe from our planet. By the time it takes the signal for covering the path from Earth to the probe and back we determine the distance, and by the frequency variation of the signal — that is, the Doppler effect — the escape velocity. Moreover, ground receiving devices measure the station's angular coordinates, that is, the angles, at which the interplanetary station is seen from Earth. The bilateral communication with the station is realized by the center of remote space communication with the aid of supersensitive receivers and powerful transmitters.

One of the most responsible systems of the probe is the orientation and correction system. It assures the required orientation of the probe at various stages of the flight.

Included in the orientation system are the electronic-optical sensors, the gas jet engines, the gyroscopic station's rotation velocity measurers and guiding devices. The position of the probe in space is determined by the electronic-optical sensor, in whose visual field is the Sun, a star or the Earth. At its deflection from the assigned position, signals arrive from the sensors to the guiding system, which restores the probe to its initial position with the aid of micro-engines.

The responsible problem of the guidance system is the sustaining of constant orientation of solar cells so that they be lit by direct rays of the Sun during the entire flight. For the constant orientation of the station at the Sun a special electronic-optical sensor is used, which allows the search for the Sun from any station's position in space. After the Sun hits the visual field of sensor's central tube, this orientation is sustained by the guidance system till the next maneuver.

Prior to the beginning of radiocommunication the station must, with aid of the parabolic antenna, occupy such a position that the antenna axis during the session be directed at the Earth with a precision to fractions of angular degree. This orientation is obtained with the aid of a sensor consisting of two optical tubes, the "solar" and the "terrestrial".

The axis of the "terrestrial" tube is directed along the axis of the parabolic antenna, while the "solar" tube may rotate according to the variation of the angle Sun — station — Earth. During the probe's flight through the interplanetary space trajectory the orientation has the following sequence: the station rotates and encompasses the Sun by the "solar" tube; then the station's rotation is materialized along the axis of the "solar" tube till the Earth hits the visual field of the "terrestrial" tube. After that the rotation of the station ceases, the transmitter is switched onto the parabolic antenna and the transmission of information begins. The orientation of the station at both heavenly bodies is sustained in the course of the entire session with the aid of the guidance system. At the end of the session the station returns to the constant orientation of solar cells at the Sun.

A special astro-pickup is foreseen for orienting the station during the correction maneuver. With the help of the latter the longitudinal axis of the motive installation, coinciding with the longitudinal axis of the station, may be oriented in any direction. This pickup is a complex electronic-optical device having mobile optical tubes: the "solar" and the "stellar". The angles between the station's longitudinal axis and the optical axes of both these tubes are determined by computation from the results of trajectory measurements; the values of these angles are transmitted on board by the command radioline. After their transmission the rotation of optical tubes is realized into the preassigned position relative to the longitudinal axis of the station. At the beginning of the astrocorrection session the station effects a turn in space so long as the visual field is not hit by the Sun at first, and by the Canopus star afterward. Since the sensor's tubes are already turned at preassigned angles, the axis of station's engine occupies the position in space required for correction. At the same time, a high precision is attained in the orientation — to few angular minutes.

A liquid-fuel engine and two gyroscopic devices are also part of the correction system. One of the latter is designed for memorizing the the station's position in space prior to switching on and during the operation of the engine, the other is meant for switching off the engine when the preassigned velocity has been attained.

FLIGHT OF THE AUTOMATIC STATIONS TO PLANET VENUS

Venus-2 was launched on 12 November 1965 with the view of flying past Venus in the vicinity of the planet. In order to achieve this it was necessary to have it fly past Venus on the side illuminated by the Sun at a distance of not more than 40 000 km from its surface. On 16 November, Venus-3 was launched with the view of reaching the Venus' surface.

For the facility of radiocommunication the station must have effected the landing at the center of the disk visible from Earth.

The placing of each of the stations into interplanetary trajectories was realized in two stages. At first the last stage of the carrier-rocket was placed into the Earth's satellite orbit together with the station. Then, the firing of the last stage had to take place at a preassigned time, placing the station in the flight trajectory to Venus. The schemes of these stations' flight to Venus are presented in Fig. 2 alongside with the positions of the planet at various moments of time.

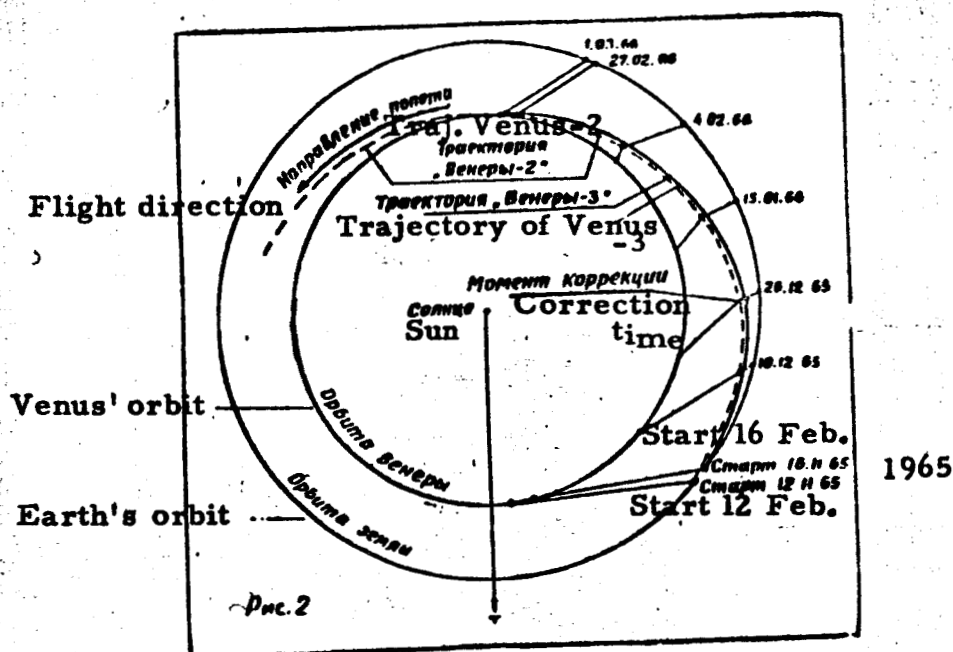


Fig. 2

The completion of the proposed problems requires a very high precision in placing the interplanetary probes into trajectories to Venus.

At time of placing into interplanetary trajectory and last stage's engine switch off the speed of both stations constituted about 11 500 meters/second. At such velocities the deflection in the magnitude of the velocity at the latter portion of the above operation by 1 meter/sec will result in deflections near the planet by values of the order of some 30 000 km. To ensure such high precisions is beset with great technical difficulties; that is why the possibility of effecting corrections in flight is foreseen for both probes.

The motion correction could be carried out several ^{times} by either "solar-stellar" or "solar" methods. In the first case there operates on board a "solar-stellar" orientation system which utilizes as reference heavenly bodies the Sun and the star Canopus. This system allows, in principle to orient the axis of the correcting engine in any direction in space, which provides the possibility of assuring not only the hitting of the preassigned point of the planet, but to change the time of its meeting the planet. The latter is indispensable so as to assure the stations' flight up to Venus in the period of their visibility from the center of the long-range space communications.

In the case of "solar" correction the axis of the correcting engine is directed either at the Sun or from the Sun, depending upon the deflection from the real trajectory from the computed, and is being fixed. The value of the correction velocity and the "sign" determining its direction are transmitted on board. This method, not involving the utilization of the star, is technically simpler. However, for some deflections of the true trajectory from the calculated one it introduces specific limitations and requires the conducting of some corrections at specific moments of time. Both these correction methods were verified earlier at flights of Zond-1 and -3.

The variation of flight trajectory parameters of Venus-2 and Venus-3 and the determination of their motion forecast were materialized by a complex of radiomeasurement means and of computing centers.

The remoteness of the stations, their radial velocity and their angular coordinates were determined in the process of trajectory measurements. This provided the possibility to determine with high precision the velocity components, the coordinates and other elements of stations' trajectories.

The results of trajectory measurements were processed in computers independently by several computing centers. A large volume of data was processed with the view of obtaining the prognosis of stations' motion with highest possible precision. For Venus-3, in particular, measurements were conducted in 31 radiocommunication sessions, including the portion of trajectory prior to correction — in 16 sessions. The total volume of measurements information then obtained exceeded 1 300 measurements of remoteness 5000 measurements of radial velocity and 7000 measurements of angular coordinates.

As a result, it was established after the station has been placed into the interplanetary orbit that the trajectory of Venus-2 was close to the computed. The minimum distance of flight by the planet was 24 000 km from its surface and the flight took place by the illuminated side, thus in accordance with the preassigned requirements, which allowed to forego the corrective operations. The flight scheme of Venus-2 past the planet is shown in Fig. 3.

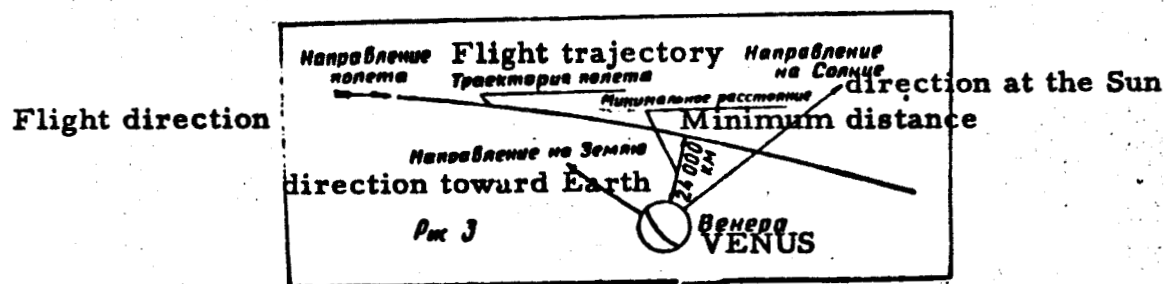


Fig. 3

According to measurement data, Venus-3 should have flown, after its placing into the interplanetary orbit, at the distance of 60 550 km from the center of the planet at 00 00 hours 37" on 1 March 1966. At that time the station could not be observed from the center of remote space communications. That is why a correction had to be made; the latter was completed on 26 December 1965 at 18 04 hours, when the station was at the distance of — 12, 900, 000 km from the Earth. This was accomplished by the "solar-stellar" orientation method.

The required magnitude of the corrective pulse, alongside with the two angular settings were transmitted on board of the station. As a result of correction, the radial velocity had to change by 19.75 meter/sec. According to the assignment the station should have reached Venus' surface at 10 00 hours Moscow time on 1 March 1966 at the center of the disk visible from Earth. However, immediately after the correction a factual change in the radial velocity was recorded: it constituted 19.68 meter/sec, differing only by 0.07 meter/sec from the assigned quantity. Such low deflections in the correction velocity could be assured only by the high precision in the orientation and in working out the pulse for the corrective engine. The systematic processing of trajectory measurements, effected through the correction time on 15 February 1966 inclusive, has shown that the true trajectory of Venus-3 differed little from the preassigned, and that the deflection of the true landing point from the computed did not exceed 450 km. The encounter time of Venus-3 with the planet's surface corresponded to 09 hours 56 minutes 26 seconds Moscow Time on 1 March 1966, which differed from the preassigned by less than 4 minutes. At the same time, the angle between the direction at the Earth and the local vertical at landing point constituted 1 degree 30 minutes. Therefore the necessity of effecting an additional correction no longer existed.

In the process of analysis of the measurement material and of computation of station's true orbit parameters serious attention was drawn to the estimate of maximum errors in the determination of the coordinates of Venus-3 landing point on Venus' surface.

It is well known that the precision of motion prognosis is determined by two groups of errors:

- by small random and systematic errors in the measurements by radio-engineering means of remoteness, radial velocity and angles;
- by errors connected with the knowledge of the astronomical unit and other astronomical constants.

A detailed processing of trajectory measurements has shown that because of instrumental errors of measurement, the maximum deflection of the true landing point from that forecast constitutes no more than 600 km.

As to the maximum error in the forecast of the coordinates of the landing point on account of errors in astronomical constants, it does not exceed 500 km.

Therefore, the aggregate maximum error of computation of coordinates of station's landing point, obtained as the root-mean value of these quantities, does not exceed 800 km. This means that the true trajectory of station's motion may differ from that determined by the results of measurements (it is called as the "real" in Fig. 4)* on account of the indicated sources of error, by a value of ± 800 km. Consequently, the true trajectory will be situated in a narrow tube, shown in Fig. 4 as the "boundary of the possible trajectory deflections". The error in the time of encounter of the station with the planet constitutes, according to the results of calculations, only ± 5 minutes.

Subsequent measurements at station's flight up to the planet have shown only the acceleration of station's motion caused by the direct planet attraction.

It must be noted that being endowed with a substantial mass, nearly equal to that of the Earth, Venus strongly attracts any spatial body approaching it. Thus, for example, the region of Venus-3 encompassing, that is, the region of trajectories of Fig. 4 hitting it, is determined by a circle having a radius of 15 000 km, considerably exceeding the geometrical radius of Venus, which is of 6 100 kilometers. Consequently, hitting the planet was assured even in the case whereby the errors in coordinate prognosis of the point of landing were 10 - 15 times greater than those indicated.

As a result of the flight of Venus-2 and Venus-3 a considerable, diversified material of trajectory measurements was obtained, which constitutes an independent scientific value for the study of the problem of superdistant measurements and interplanetary flights. The complexity of the problem of projecting interplanetary space probes consists in that we know little of the physical conditions in interplanetary space, which are difficult to simulate during the tests of similar probes. As a matter of fact the final tests of the airborne equipment and of probes as a whole are taking place in flight, during launchings for specific purposes.

* See Fig. 4 on page 15.

The flight of Venus-2 and Venus-3 has shown that the operating conditions of space probes in the immediate vicinity of Venus are still little studied. A notable temperature increase was noted at time of nearing the planet, just as was the case on Mariner-2, having exceeded the computed values. Noted also were certain disruptions of radiocommunications. The last session with Venus-3, when the latter approached Venus, did not materialize. The causes of the disruption could not be ascertained as yet. At present, a detailed analysis of probes' operations is being made according to telemetry data of preceding sessions.

At time of Venus-2 approach to Venus, appropriate command was given which switched on the automatic regime of investigations in the by-pass session according to preassigned program. No confirmation of this command passage was received. The result of the experiment will become known, if radiocommunication with Venus-2 is restored.

At present Venus-2 pursues its flight along the heliocentric orbit. On 4 March its distance from Earth was nearly 65 000 000 kilometers.

63 sessions in all were held with Venus-3, and 26 — with Venus-2 for the entire flight. A large number of sessions were conducted with Venus-3 with the object of a more precise ^{motion}/trajectory measurement. Scientific data and the telemetric information on the apparatus operation were constantly transmitted to Earth.

PHYSICAL INVESTIGATIONS IN FLIGHT

The interplanetary space is the object of numerous scientific investigations. The flux of ionized gas, that is, the solar wind, emerges from the Sun in all directions at a speed near 500 km/sec. The active regions of the Sun eject episodically particle fluxes with a velocity of 1000 — 3000 km/sec; they eject at times particles of very high energy or solar cosmic rays. Particularly great is the concentration of charged particles near the Earth, in its radiation belts, where these particles trap the geomagnetic field. Then cosmic rays, that is, particles of enormous energies, hit the solar system from without with a speed very near that of the light. The solar particle fluxes carry along a weak, though quite measurable magnetic field; it is measured by space rockets drifting beyond the Earth's magnetosphere.

The study of all these events offers a particular interest in time

of solar activity minimum, which is now the case, when the process of episodic matter ejections from the Sun, isolated in time, and the ensuing magnetic disturbances may be traced more clearly owing to their relative rarity. The study of the transitional region between the Earth's magnetic field and the interplanetary magnetic field, that is, the boundary of the Earth's magnetosphere, is particularly essential.

The exit of the probe beyond the magnetosphere allows the study of the low-energy component of cosmic rays, which does not reach the Earth's surface because of the geomagnetic field. This component is precisely the one which conditions the variation of cosmic ray intensity in the course of the 11-year cycle of solar activity, and also the sudden rises of radiation, so dangerous for astronauts during the solar chromospheric flares. Of great interest also is the study of the variation of cosmic ray intensity when drifting away ^{from} or nearing the Sun.

To study the physical conditions in space, the following devices were installed aboard Venus-2 and Venus-3:

- a three-component ferrosonde magnetometer for measuring interplanetary magnetic fields;
- gas-discharge counters and a semiconductor detector for the investigation of cosmic rays;
- special pickups (traps) for the measurement of charged particles of low energies and the determination of the magnitude of solar plasma fluxes and their energy spectra;
- piezoelectric sensors for the investigation of micrometeorites;
- a radio receiver for the measurement of cosmic radioemission in the 150, 1500 meter and 15 km wavelengths.

The data obtained during the flight of Venus-2 and Venus-3 are now being studied. The results will be published in scientific journals.

*** THE END ***

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Consultants & Designers, Inc.
Arlington, Virginia

Translated by ANDRE L. BRICHANT
on 11 - 13 March 1966

На снимках:

**вымпел и
медаль,
доставленные
советской
автоматической
станцией
на Венеру**



1 марта автоматическая станция «Венера-3» достигла планеты Венера и доставила на ее поверхность вымпел с Гербом СССР. Вымпел представляет собой полый шар, на поверхности которого выгравированы контуры Земли. Внутри шара — медаль, на одной стороне которой Герб Советского Союза, на другой — изображены планеты Солнечной системы. (Статью о полете автоматических станций «Венера-2» и «Венера-3» читайте на 4-й странице).

View of the pennant (upper right) delivered to Venus's surface.
The lower photographs show both sides of the medal inside the sphere, the right-hand photograph showing the side of the medal with the planets of the solar system and the respective positions of the Earth and Venus at time of impact on 1 March 1966.

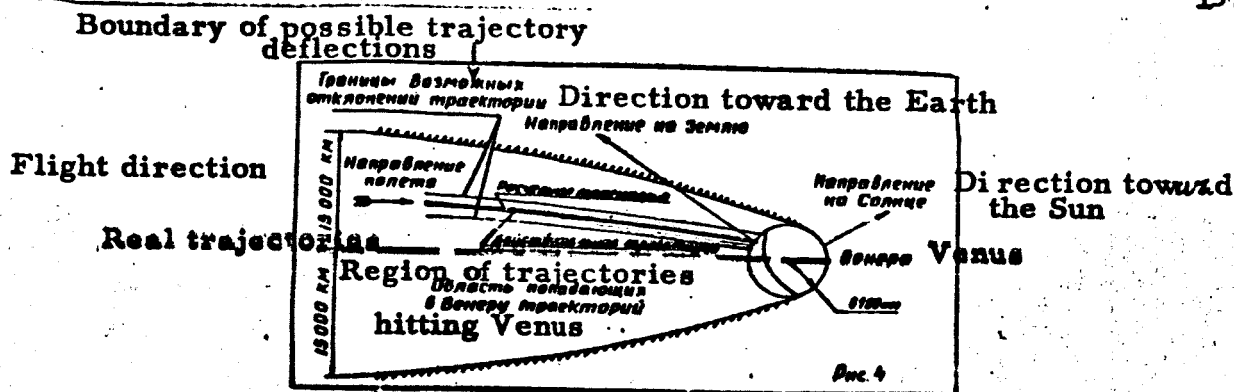


Fig. 4

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